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Fibre Laser Welding of HY-80 Steel

Proceedure Development and Testing

Christopher Bayley
DLP

Neil Aucoin
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Xinjin Cao
NRC IAR AMTC

Defence R&D Canada – Atlantic

Technical Memorandum
DRDC Atlantic TM 2009-187
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Principal Author

Original signed by Christopher Bayley

Christopher Bayley

Group Leader/Materials and Corrosion

Approved by

Original signed by Terry Foster

Terry Foster

Head DLP

Approved for release by

Original signed by Ron Kuwahara for

Calvin Hyatt

Chair DRP

Abstract

The metallurgical and mechanical properties of a series of autogeous fibre laser welded joints were carried out. These welds were made between two butt joined slices of 5 mm thick HY-80 material over a range of heat inputs extending from 75 to 240 J/mm. Apart from the increasing width of the fusion and heat affected zones with increased heat input, the metallurgical structures of the welds were similar. In all cases, the fusion zone of the weld was found to have the consistent hardness of an untempered martensite. Mechanical characterization of the welds showed that while the tensile strength exceeded the base metal requirements, under impact loading conditions the fusion zone failed in a brittle manner.

Résumé

L'analyse des propriétés métallurgiques et mécaniques d'une série de joints réalisés par soudage autogène au laser à fibre a été effectuée. Ces soudures ont été réalisées entre des pièces d'acier HY-80 d'une épaisseur de 5 mm placées bord contre bord avec une plage de températures d'entrée de 75 à 240 J/mm. À l'exception de l'accroissement de la largeur des zones touchées par la fusion et par la chaleur en proportion de la température, les structures métallurgiques des soudures étaient semblables. Dans tous les cas, la zone de fusion de la soudure présentait la dureté uniforme d'une martensite non trempée. La caractérisation mécanique des soudures a révélé que, alors que la résistance à la traction dépassait celle des exigences relatives au métal de base, la zone de fusion se montrait cassante lorsqu'elle cédait en subissant une charge d'impact.

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Executive summary

Fibre Laser Welding of HY-80 Steel: Procedure Development and Testing

Christopher Bayley, Neil Aucoin, Xinjin Cao; DRDC Atlantic TM 2009-187; Defence R&D Canada – Atlantic; September 2010.

Introduction or background: Preliminary welding procedures were developed as an alternative approach to the current practice of oversizing damaged threads. These welding procedures would use a fibre laser to fuse a series of cylindrical inserts to the interior bore of the damaged thread. Fibre lasers are particularly well suited to this application as both their fusion and heat affected zones are narrow while having deep penetration.

Results: The influence of both the laser power and travel speed on the weld metallurgical and mechanical properties was carried out. Metallurgically, increasing the heat input of the welding process increased both the width of the fusion and heat affected zones of the weld, while generating an untempered martensitic microstructure. In addition, higher heat inputs also coincided with an increased porosity.

Mechanically the weld strength was found to exceed that of the base metal, while under impact conditions the welds failed in a brittle manner.

Significance: There remains significant welding procedure development effort required for the use of an autogenous fibre laser welding for thread repair applications. This would include not only the development of weld tempering procedures in order to increase the toughness of the as-cast microstructure in the fusion zone, but also weld procedural developments required to minimize porosity.

Future plans: Tungsten inert gas (TIG) weld repaired threads are currently being examined. In this process the interior bore of the damaged hole is built-up by depositing layers of filler metal. Such a TIG welding procedure is currently being qualified along with thread repair coupons which will be tested as well under quasi-static, impact, and cyclic fatigue loading conditions.

Sommaire

Fibre Laser Welding of HY-80 Steel: Procedure Development and Testing

Christopher Bayley, Neil Aucoin, Xinjin Cao; DRDC Atlantic TM 2009-187; R & D pour la défense Canada – Atlantique; Septembre 2010.

Introduction ou contexte : Des procédures de soudage préliminaires ont été élaborées comme méthode de remplacement de la pratique courante qui consiste à surdimensionner les filets de soudure endommagés. Dans cette pratique, on utiliserait un laser à fibre pour fusionner une série d'inserts avec la tranche intérieure du filet endommagé. Les lasers à fibre se prêtent particulièrement bien à cette application, car la zone de fusion et la zone touchée par la chaleur demeurent étroites malgré la grande profondeur de pénétration du soudage.

Résultats : L'influence de la puissance du laser et de la vitesse de déplacement sur les propriétés métallurgiques et mécaniques de la soudure a été analysée. Sur le plan métallurgique, l'accroissement de la quantité de chaleur produite par le processus de soudage entraînait un élargissement de la taille des zones touchées par la fusion et par la chaleur, alors que le processus générait une microstructure martensitique. De plus, l'accroissement de la température générée coïncidait avec un accroissement de la porosité.

Sur le plan mécanique, la résistance à la traction dépassait celle des exigences relatives au métal de base, mais la zone de fusion se montrait cassante lorsqu'elle cédait en subissant une charge d'impact.

Importance : Des efforts importants doivent encore être consacrés à l'élaboration de la procédure de soudage autogène par laser à fibre pour les applications de réparation de filets. Ceci comprendrait non seulement des procédures de trempe de la soudure pour améliorer la résistance de la microstructure résultante dans la zone de fusion, mais aussi l'élaboration d'éléments procéduraux en vue de réduire la porosité.

Perspectives : On examine actuellement la réparation des filets au moyen du soudage au tungstène sous gaz inerte (TIG). Dans ce processus, on reconstruit la face interne de la brèche en déposant des couches successives de métal de remplissage. On procède à la qualification de cette procédure de soudage TIG avec des éprouvettes de réparation de filets qui seront soumises à des essais dans des conditions de charge semi-statique et avec impacts, et avec mise sous charge cyclique entraînant la fatigue.

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1 Background

First level attachments penetrate through a submarine pressure hull and are typically fastened with a ring of studs, which are threaded into the pressure hull. Over the platform's lifetime, these threaded connections are expected to fail or become damaged, necessitating either replacement or refurbishment. One corrective approach is to oversize the damage holes and retap with a larger diameter thread, which requires the use of step studs. However, there are geometrical limitations to the number of times the holes can be oversized and tapped, and structural consequences to the use of step studs.

An alternative approach proposed by The Welding Institute (TWI) enlarges the damaged thread, and back fills this cavity with weld metal. This deposited weld metal is subsequently tapped with the original thread diameter [1] and reuses the original stud design. When flaws were introduced at various subcritical locations, failure under static, dynamic and cyclic conditions were limited to the bolt, and deemed to represent a satisfactory repair procedure. However, the plate material thickness and build-up diameters are not representative of the VICTORIA class pressure hull.

While the TWI used an arc welding procedure to back fill the threads, the use of a fiber laser welding process could be advantageous and hence a high energy-density laser beam is being examined as an alternative approach. Laser welds are characterized by their small heat affected zones, deep and narrow fusion zones, and low heat input. This low heat input results in low levels of residual stress and welding induced distortion which are beneficial for meeting the tight machining tolerances of these threads.

Recently, the introduction of fibre lasers has brought significant improvements in the laser beam technology and has increased the potential applications of lasers in industry. Fibre lasers are essentially maintenance-free during their entire lifetime and pose improved optical performance, better systems flexibility, high component yield, long uptime and improved reliability. The versatile fibre lasers offer the ultimate for solid state laser systems and could replace conventional CO_2 and Nd: YAG lasers in the future. The fibre laser produces high beam quality preserved with fibre optic delivery. The spot size of fibre lasers is extremely small (up to 5 times smaller than that of Nd: YAG laser), predictable and consistent at all power levels during the entire life of the laser, a critical feature to improve the process reliability. Fibre lasers, therefore, can weld and repair faster at lower power levels because of the small spot size and high beam quality. This means that high quality precision welding and repair can be performed accurately, even for complex components without causing great distortion or potential damage to the surrounding regions of the components. Due to the small size of the laser beam, the use of small diameter welding wire becomes possible. Therefore, small and complex components, particularly with geometries such as deep holes, borders, pockets and other intricate profiles, can be repaired. In addition, fibre laser equipment is very compact and fit for flexible and potentially mobile uses, especially for those fields of applications currently inaccessible to laser technology (e.g. 0.5 m^2 footprint for fibre laser and 11 m^2 for a lamp-pumped Nd: YAG at 4 kW power). Despite these promising aspects, no work has been reported to date on the application of fibre laser technology to the repair of the first level threads.

The present project was initiated to explore the feasibility of repairing first level thread components for submarine applications using a fibre laser and an insert gas adding technique.

The study is concentrated on investigating the effects of heat input on the metallurgy and mechanical properties of autogenous butt-joints.

2 Welding

The material used in this study was quenched and tempered martensitic HY80 steel which conforms to MIL-S-1621 [2]. The testing coupons with dimensions of approximately 177.8 × 44.5 × 5 mm were cut from the HY80 plate as indicated in Figure 1. The faying face was machined and cleaned prior to the clamping.

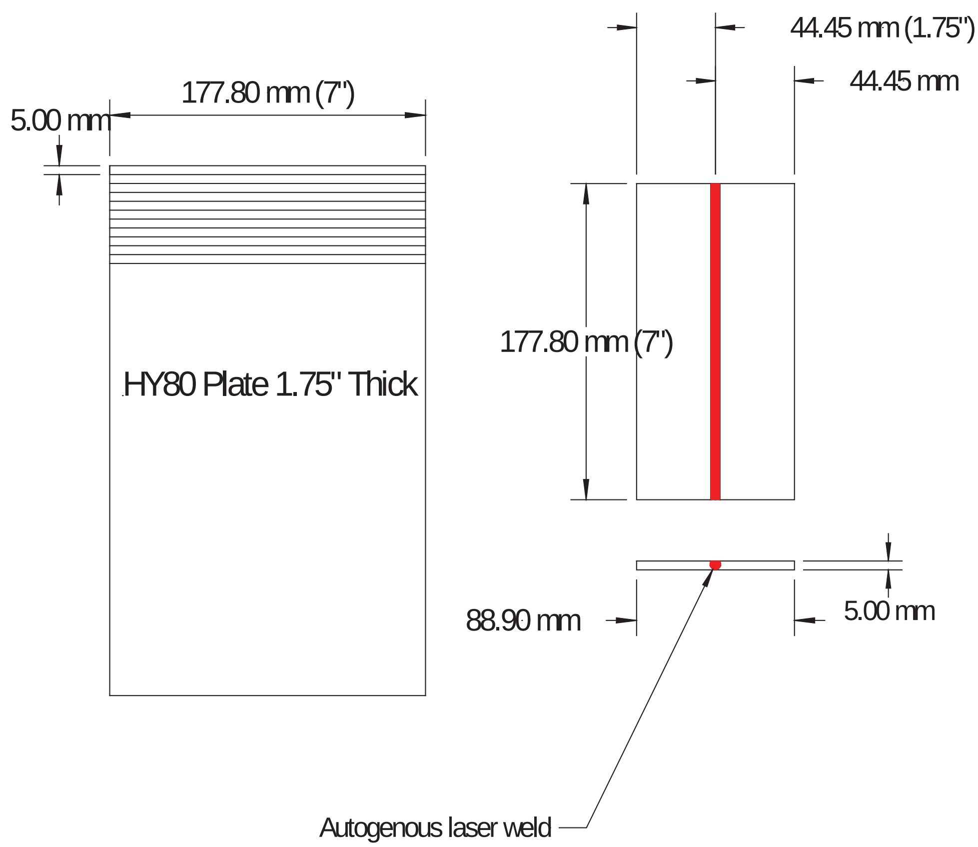
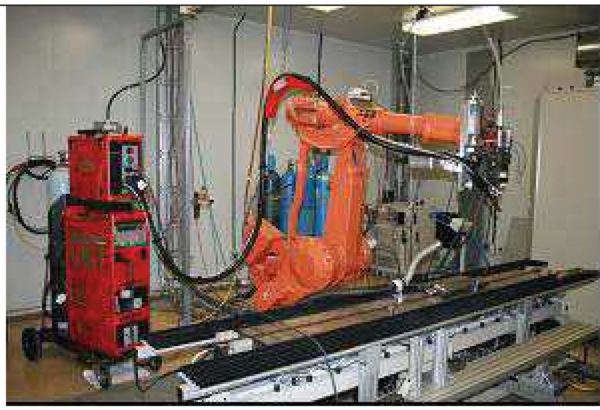
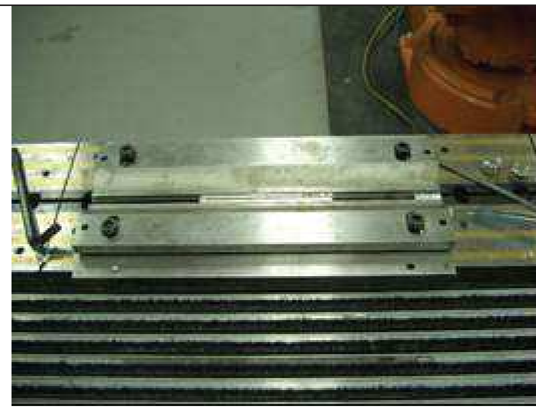


Figure 1: Material extraction from HY80 Plate

The welding equipment shown in Figure 2 is a newly installed 5 kW continuous wave (CW) YLR-5000 IPG solid-state fibre laser system equipped with an ABB robot and a magnetic holding fixture located at Aerospace Manufacturing Technology Center of the National Research Council Institute for Aerospace Research (NRC-IAR-AMTC). A collimation lens of 150 mm, a focal lens of 250 mm and a fibre diameter of 200 µm were employed to produce a nominal focusing spot diameter of approximately 0.33 mm. During welding, the welding head inclined approximately 5º from the vertical towards the welding direction (the tip backwards). During laser welding, high purity argon at a flow rate of 50 cfh (cubic feet per hour) was used to shield the top surfaces of the work-pieces. The bottom surfaces were shielded using helium at a total flow rate of 40 cfh. The laser beam was focussed at –2 mm (i.e. 2 mm below the top surface of the work-piece). The welding experiments were first carried out at various heat inputs (i.e. various laser powers and welding speeds) on 5 mm thick low carbon steel sheets to obtain fully penetrated autogenous butt joints. Table 1 lists the main processing parameters used. No joint gap or filler wire were used. Two joints were produced using each set of processing parameters. In total, five pairs of single pass autogeneous butt welds were made from the 5 mm thick slices of HY-80.



(a) 5 kW fibre laser system



(b) Fixture used

Figure 2: AMTC 5 kW fibre welding system and fixture used in this study

Table 1: Welding Conditions

Joint #	Sample label	Laser power (kW)	Welding speed (mm/s)	Heat input (J/mm)
170209-1	**1**	5.0	66.7	75
130209-3	3	5.0	66.7	
170209-6A	6A	4.5	41.7	108
170209-6B	6B	4.5	41.7	
170209-2A	2A	4.0	29.2	137
170209-2B	2B	4.0	29.2	
170209-5A	5A	3.5	16.7	210
170209-5B	5B	3.5	16.7	
170209-3A	3A	3.0	12.5	240
170209-3B	3B	3.0	12.5	

3 Testing

From the five pairs of duplicate welding conditions, transverse tensile, metallographic and Charpy impact bars were machined according to the specimen layout shown in Figure 3. The orientation of the Charpy specimens along the weld length was chosen in order to ensure that the crack propagated through the weld fusion zone. This specimen orientation was found by Goldak to yield a conservative estimate of the transition behaviour for narrow gap welds [3]. For the fusion zone Charpy specimens, the root radius of the milled notch was specified at the edge of the visible heat affected zone in order that the crack would be forced to initiate in the fusion zone. Unfortunately, due to a combination of misalignment and angular distortion, the Charpy Specimens needed to be milled to a constant thickness of 4.1 mm which is below the standard specimen thickness of 10mm. This thickness was also specified for the all base metal impact specimens. Along with the mechanical test specimens, metallographic samples were obtained from the weld start and terminations from each welded sample. These metallographic samples were used for both the microstructural analysis as well as micro-hardness traverses.

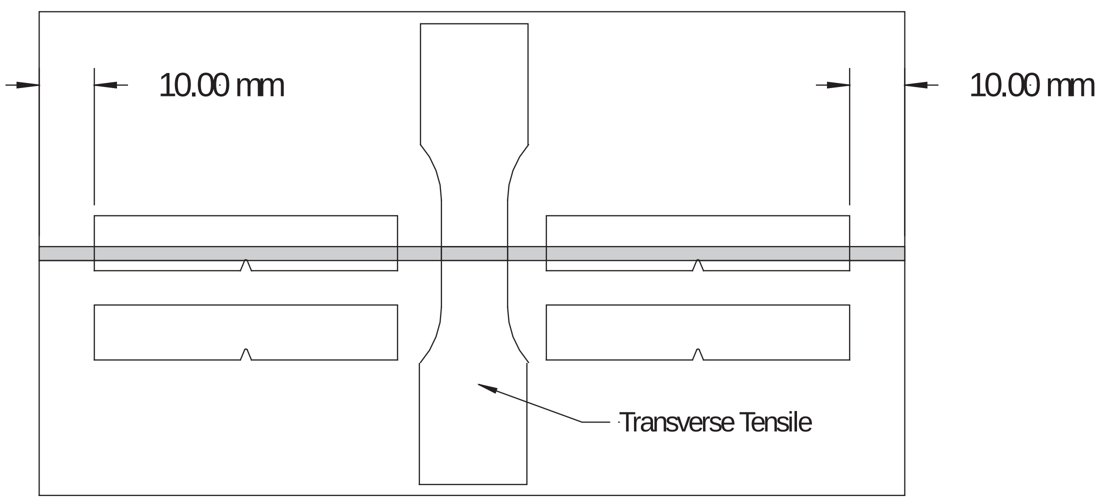
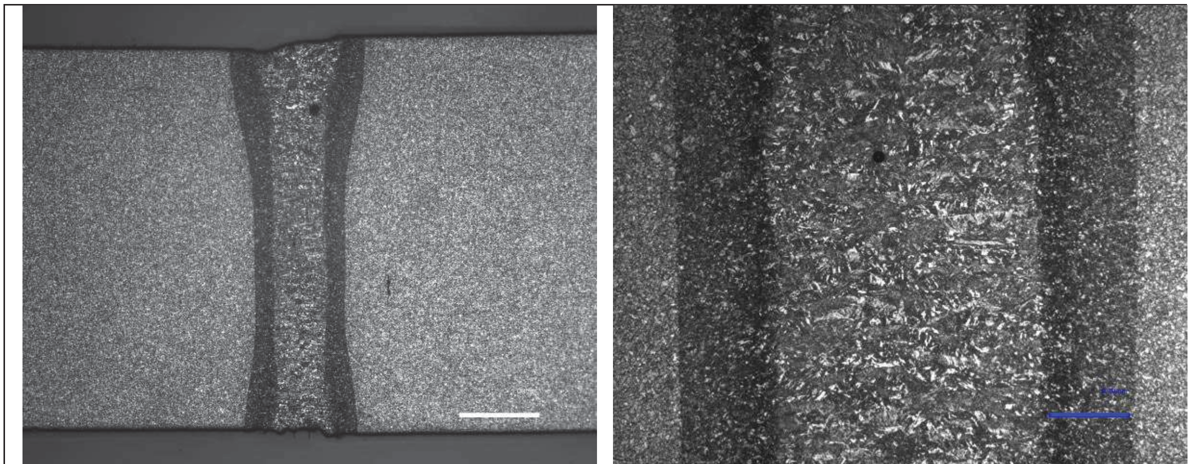


Figure 3: Specimen layout. Metallurgical samples were taken from the 10 mm ends corresponding with either the weld start or termination

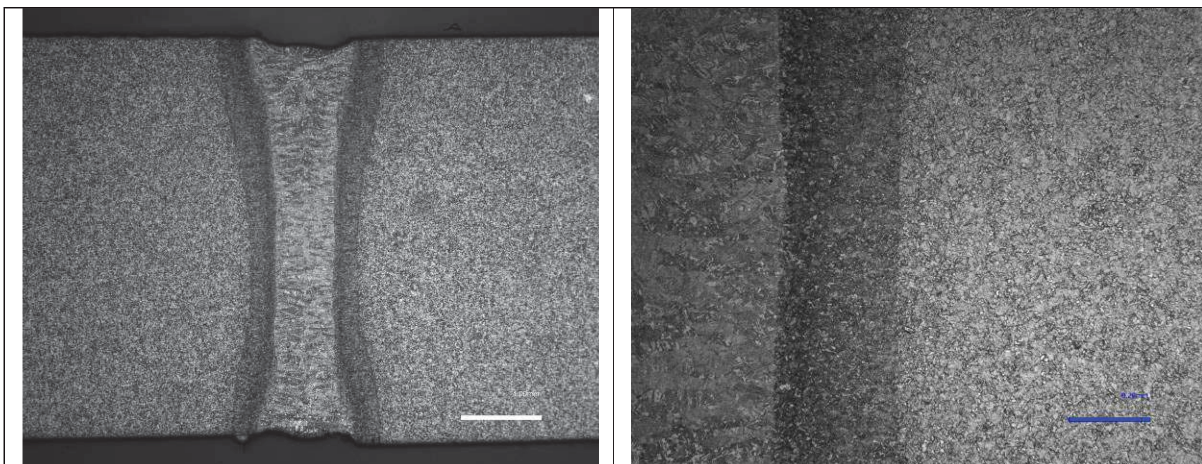
3.1 Metallography

Transverse metallographic samples were extracted from each pair of welded panels and plotted in Figures 4-8 which have been arranged with increasing heat input. In each macrograph, the Fusion Zone (FZ), Heat Affected Zone (HAZ) and Base Metal (BM) are readily distinguished.



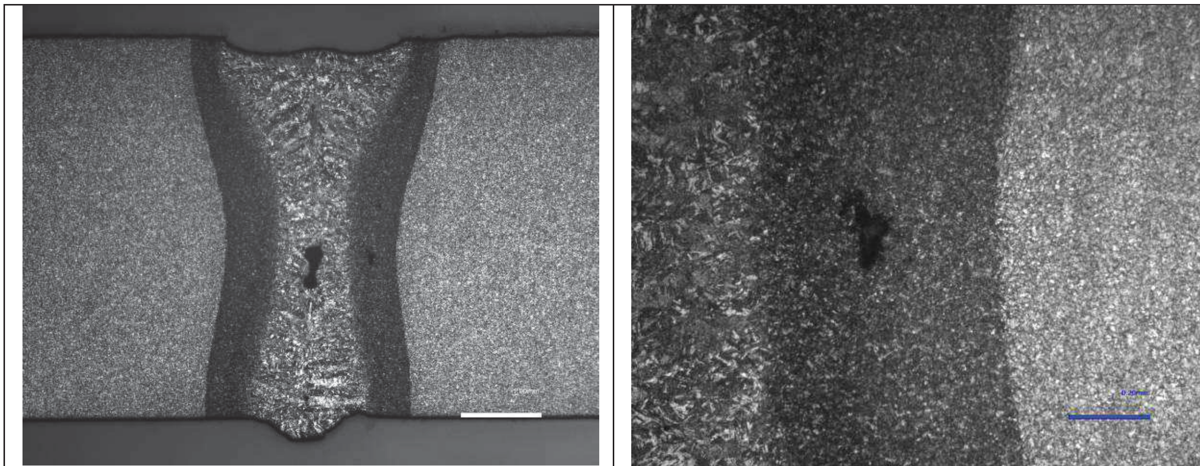
a) Macro (Scale bar represents 1.0 mm) | *b) Micro (Scale bar represents 200 μm)*

Figure 4: Welding condition of 5 kW and 66.7 mm/s (75 J/mm)



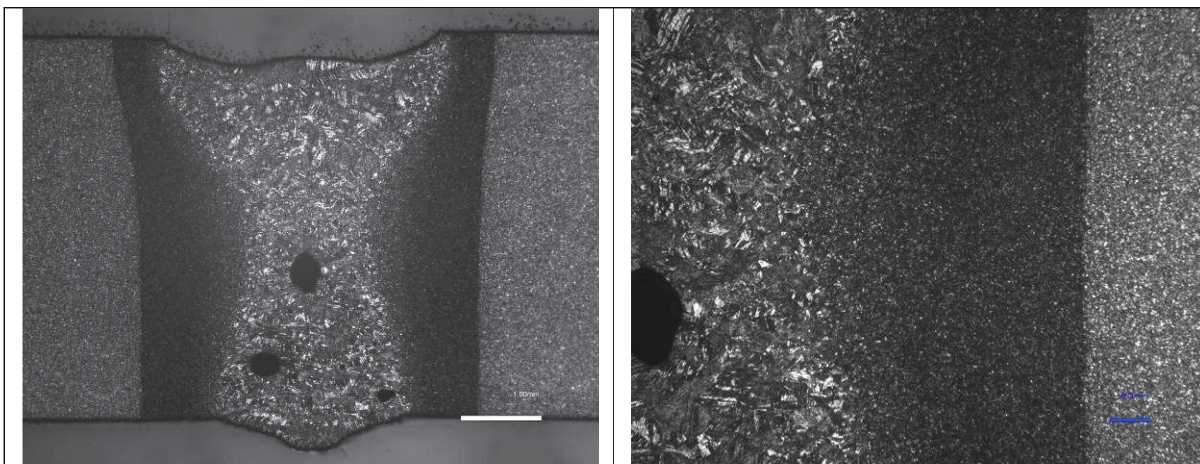
a) Macro (Scale bar represents 1.0 mm) | *b) Micro (Scale bar represents 200μm)*

Figure 5: Welding Conditions of 4.5 kW and 41.7 mm/s (108 J/mm)



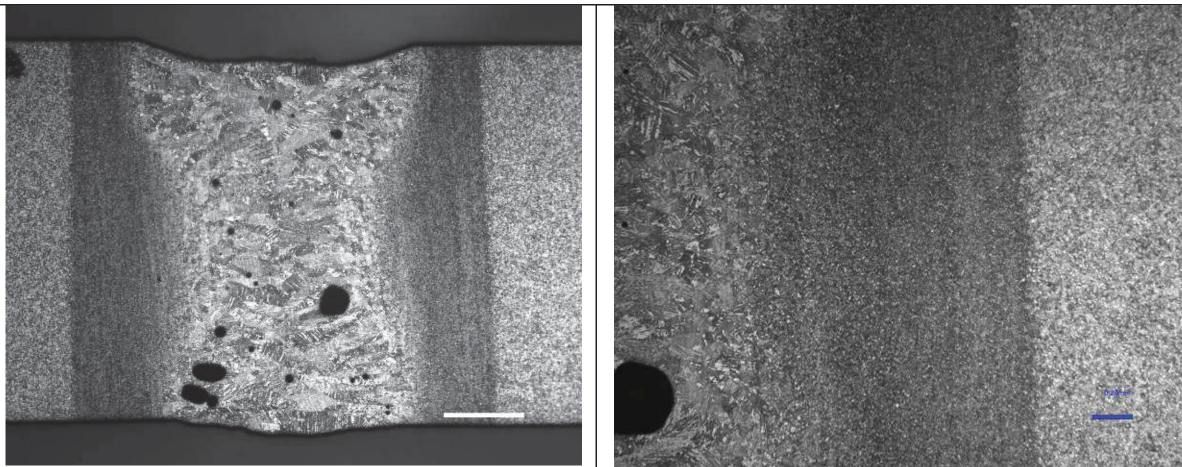
a) Macro (Scale bar represents 1.0 mm) | *b) Micro (Scale bar represents 200μm)*

Figure 6: Welding condition of 4 kW and 29.2 mm/s (137 J/mm)



a) Macro (Scale bar represents 1.0 mm) | *b) Micro (Scale bar represents 200μm)*

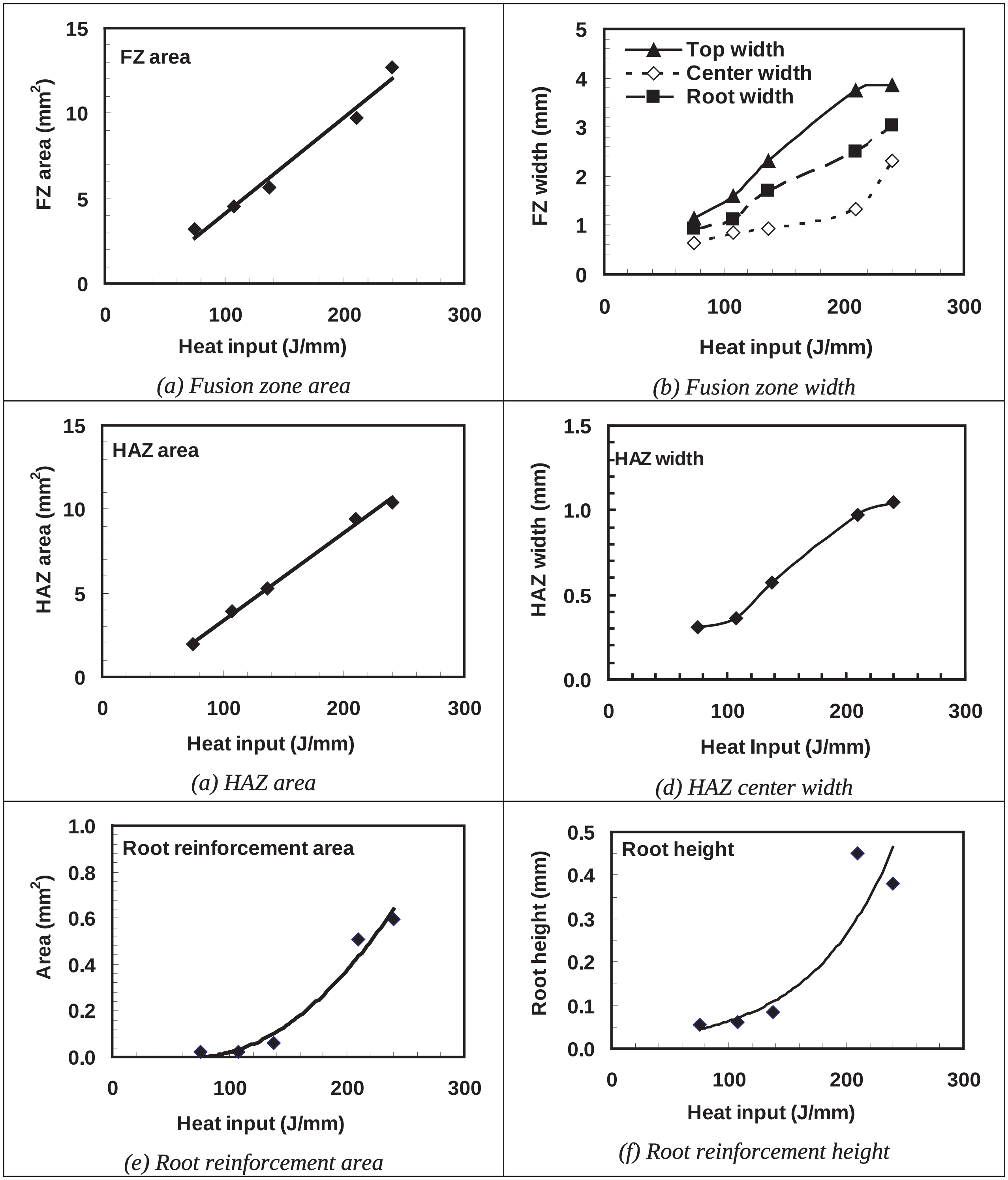
Figure 7: Welding conditions of 3.5 kW and 16.7 mm/s (210 J/mm)



a) *Macro (Scale bar represents 1.0 mm)*	b) *Micro (Scale bar represents 200μm)*

Figure 8: Welding condition of 3 kW and 12.5 mm/s (240 J/mm)

To characterize the joint shapes, the geometrical dimensions of the joints were measured and plotted in Figure 9. The areas of the fusion zone and the HAZ (both sides included for HAZ) increase with increasing heat input. The widths of the fusion zone (top, center and root) and the HAZ (center) also increase with increasing heat input.



(a) Fusion zone area

(b) Fusion zone width

(a) HAZ area

(d) HAZ center width

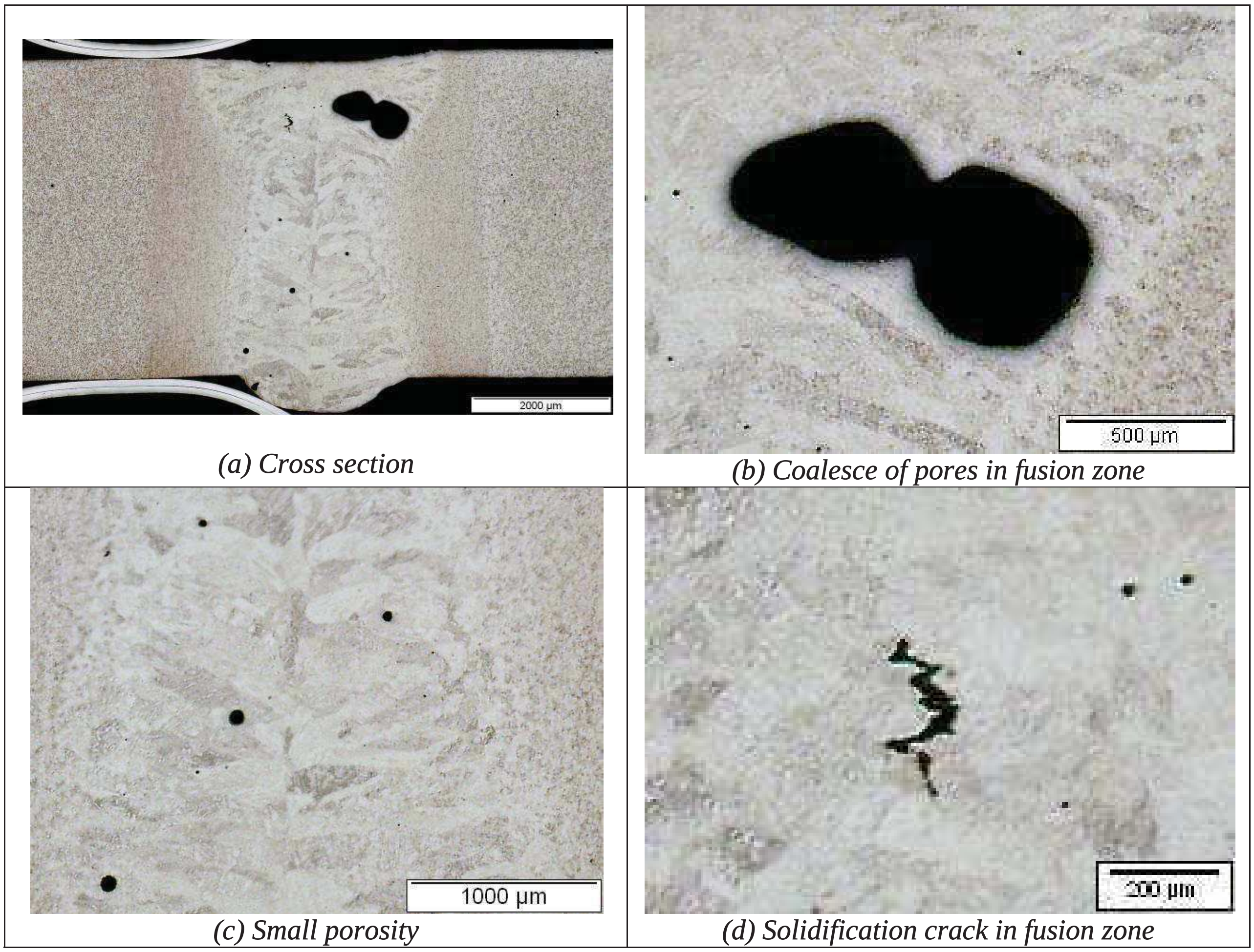
(e) Root reinforcement area

(f) Root reinforcement height

Figure 9: Effect of heat input on the joint dimensions

As shown in Figures 4-8, another visible feature in all of the macrographs is porosity within the fusion zone. Figure 10 shows the porosity defects observed at high heat input. During the flotation and rise of the pores, they can coalesce to form a larger porosity if they meet as shown in Figure 10b. The void size and area fraction are relatively low at low heat input but increase significantly at high heat input. Not only do these pores appear in the fusion zone, but also within the HAZ as shown in Figure 6b. Weld cracking was occasionally observed in the fusion zone at high heat input as shown in Figure 10d. Underfill defects were observed on both the top and root sides of the joints. Figure 11 shows the relationship of the underfill area and depth with heat input. It is clear that the underfill defects mainly appear on the top surface of the joints as shown in Figure 4-8. The top underfill area increases with increasing heat input. The maximum underfill depth also increases with increasing heat input.

In all cases the microstructures of the fusion zones are martensite as shown in Figure 12.



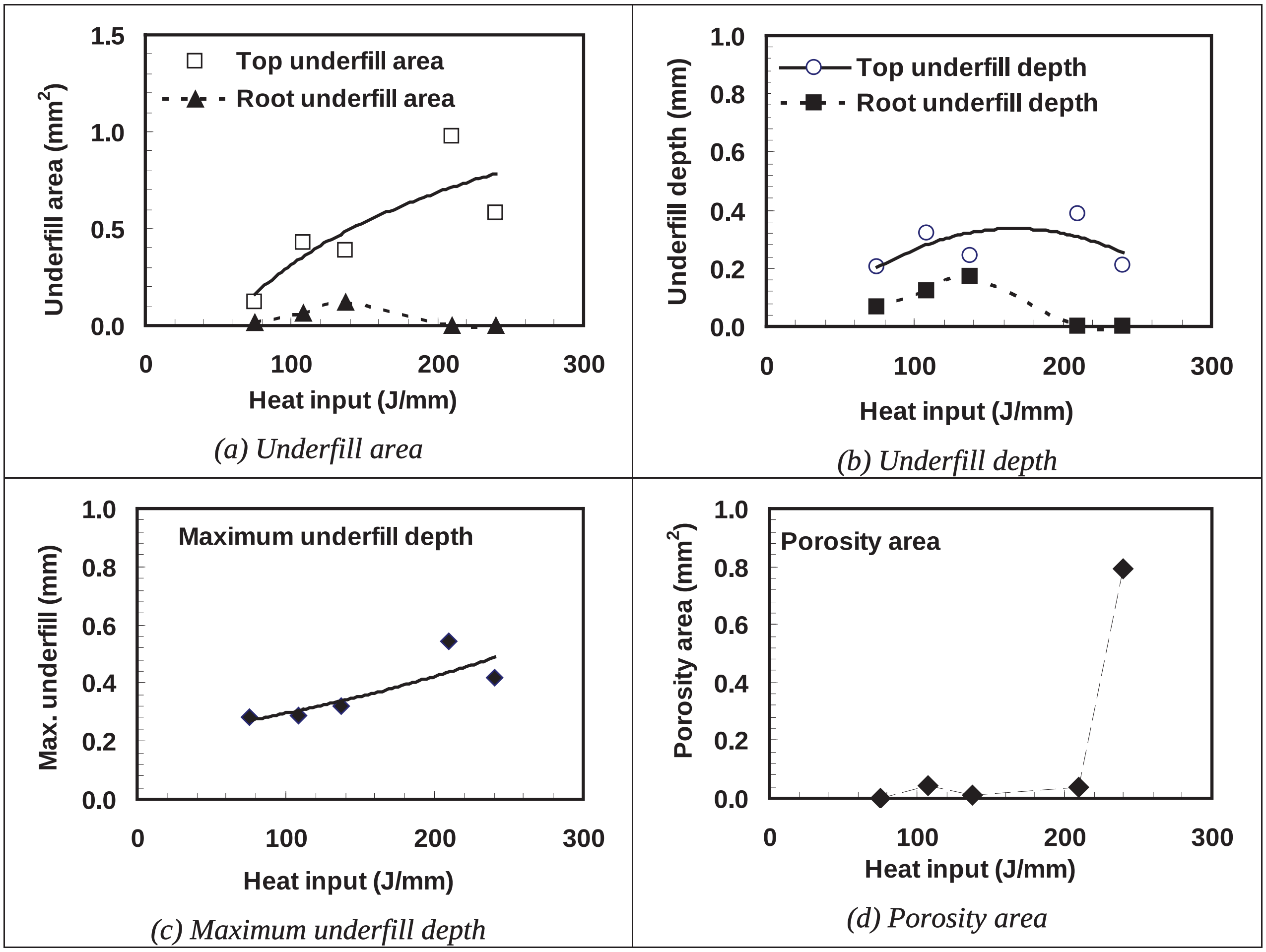
(a) Cross section

(b) Coalesce of pores in fusion zone

(c) Small porosity

(d) Solidification crack in fusion zone

Figure 10: Welding defects obtained at Sample 3A (3 kW and 12.5 mm/s)



(a) Underfill area

(b) Underfill depth

(c) Maximum underfill depth

(d) Porosity area

Figure 11: Effect of heat input on the dimensions of welding defects

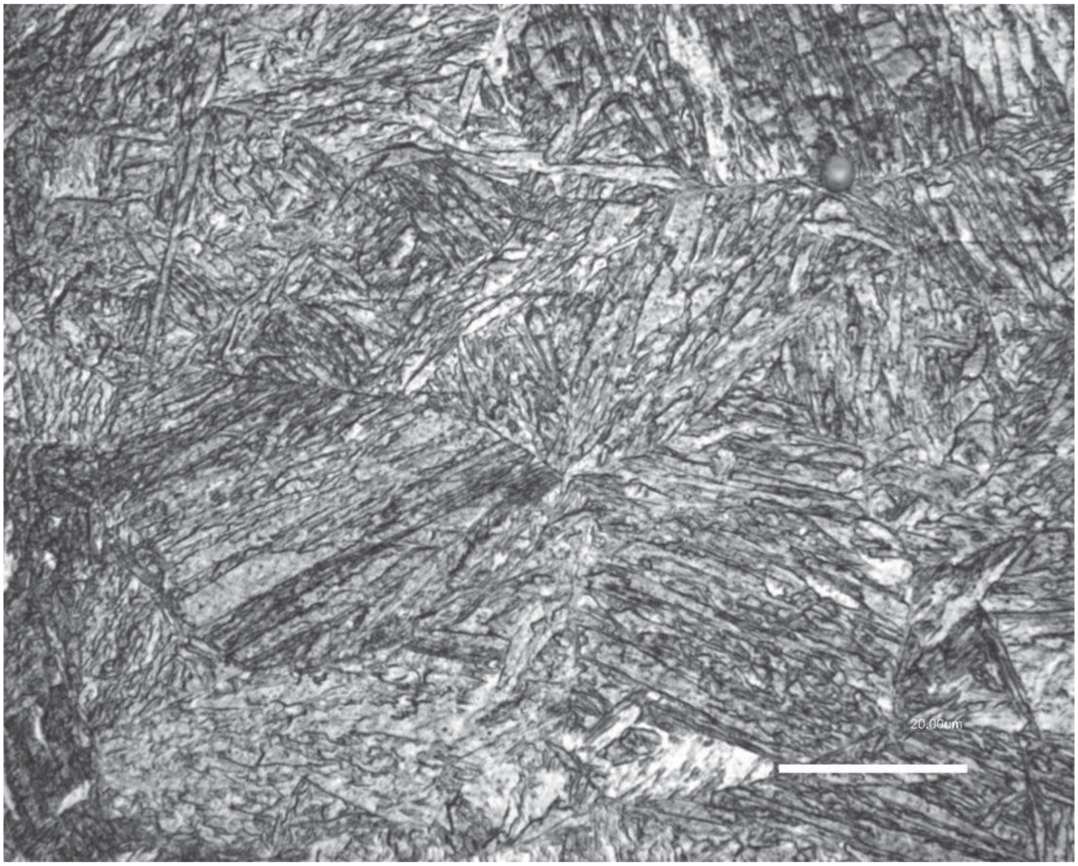


Figure 12: Fusion zone martensitic microstructure obtained from 4 kW and 29.2mm/s (137 J/mm). Scale bar represents 200 μm

3.2 Microhardness Surveys

Figure 13 shows a hardness map superimposed on a macroscopic image for the weld labelled as 170209-1 (5 kW and 66.7 mm/s). The weld fusion zone has a near constant hardness. Figure 14 shows the microhardness profiles across the welds. The visible HAZ corresponds with the region of increasing hardness.

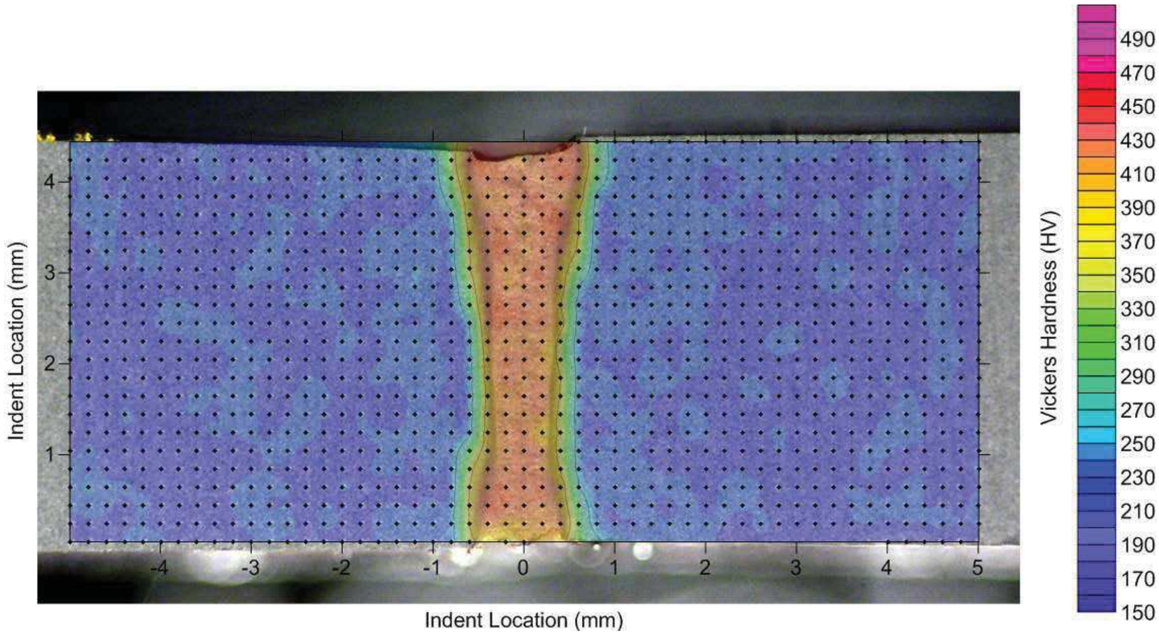


*Figure 13: Hardness map superimposed on macroscopic image for weld labelled **170209-1** (5 kW 66.7 mm/s). The weld fusion zone has a near constant hardness.*

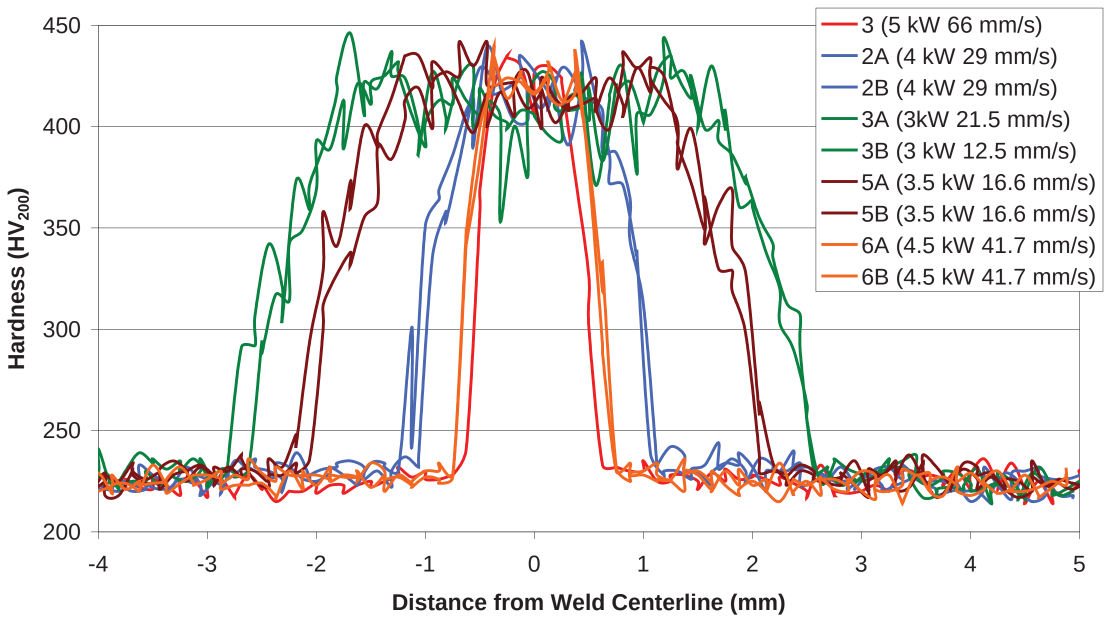


Figure 14: Microhardness profiles across the welds. The visible HAZ corresponds with the region of increasing hardness

3.3 Transverse Tensile Tests

Duplicate transverse tensile specimens were tested under quasi-static tension in a servo-hydraulic test frame in accordance with ASTM E8, AWS D1.6 and DefStan 02-770. As reported in Table 2, six of the ten specimens failed in a ductile manner with the neck occurring in between the fusion line and the radiused portion of the specimen. However, four of the ten samples suffered brittle fractures and failed outside of the specimen's gauge region. These brittle failures occurred after little or, in the case of sample 5A, no plastic deformation. The cause of the brittle fracture was subsequently determined to be from a segregation band within the base metal and, therefore, not associated with the welding procedure.

The six ductile samples were assessed in accordance with the transverse weld requirement of AWS D1.6 [4]. AWS states that tensile strength of the transverse tensile specimen must be greater than the minimum specified tensile strength of the base metal. For the case of HY-80, this is 717 MPa, and therefore according to this standard, all of the welding procedures which failed in a ductile manner met this requirement. Likewise DefStan 02-770 [5], states that a minimum strength requirement of 550 MPa yield strength (0.2% offset) and 18% strain at failure for all-weld tensile specimens. According to this standard, only specimens 1, 3, 6B, and 2A which failed in a ductile manner met this requirement.

Table 2: Transverse Tensile Results

Welding Procedure	**Yield (MPa)**	**UTS (MPa)**	**Reduction of Area %**	**Failure Strain %**	**Specimen Failure Location**
1	606	726	27.9	30.6	Ductile Failure - Weld Fusion Line
3	607	725	34.7	29.3	Ductile Failure – Base Metal
6A	**605**	**675**	**4.1**	**4.3**	**Brittle Failure – Base Metal**
6B	603	725	29.1	36.8	Ductile Failure - Weld Fusion Line
2A	602	727	37.5	18.6	Ductile Failure - Base Metal
2B	602	728	34.3	16.4	Ductile Failure - Base Metal
5A	********	**434**	**0.0**	**0.2**	**Brittle Failure – Base Metal**
5B	**597**	**690**	**4.3**	**3.1**	**Brittle Failure – Base Metal**
3A	601	734	31.9	12.2	Ductile Failure - Base Metal
3B	**597**	**707**	**4.2**	**3.7**	**Brittle Failure – Base Metal**

3.4 Impact Testing

Two weld metal and two base plate sub-size Charpy impact specimens were extracted from each of the plates, as shown in Figure 3. Due to the slight amount of angular misalignment and offset, the sub-size specimens were machined to a thickness of 4.1 mm, which is substantially less than a standard sized specimen, which has a thickness of 10.0 mm. Due to this reduced thickness, non-standard acceptance criterion for the impact testing was sought.

Def Stan 02-736 [6] reduces the Charpy impact energy in proportion to the thickness. This standard requires 80% of the full size specimen energy for a 7.5mm thickness and 70% of the full sized specimen energy for a 5 mm thickness. In addition, the fracture appearance requires that the average crystallinity of an all weld Charpy fracture surface must be not more than 55%, with no individual value greater than 70% when broken at a temperature of -50°C [5].

Using the guidance of DefStan 02-770 [5] and DefStan 02-736 [6], subsize Charpy impact acceptance criteria were developed and listed in Table 3 for both the weld and base metals. Note that these minimum shear areas are specifically for the weld metal rather than the whole fracture face. After a few initial fracture tests were carried out at -90°C, the remaining welded specimens tests were conducted at -50°C while the base metal specimens were tested over a temperature range from -80 to 20^{o}C, and plotted in Figure 15. For all of these base metal specimens, the fractures appeared 100% ductile.

Table 3: Subsize Charpy Impact Requirements

		Energy (J)			Weld Metal Shear Area (%)	
	Test Temp (C)	Thickness Factor	Ave	Ind	Ave	Ind
Welded Samples DefStan 02-770[5]	-50	70%	35J	28J	>45%	>30%
Base Plate DefStan 02-736 [6]-	-80	70%	55J	NA	NA	NA

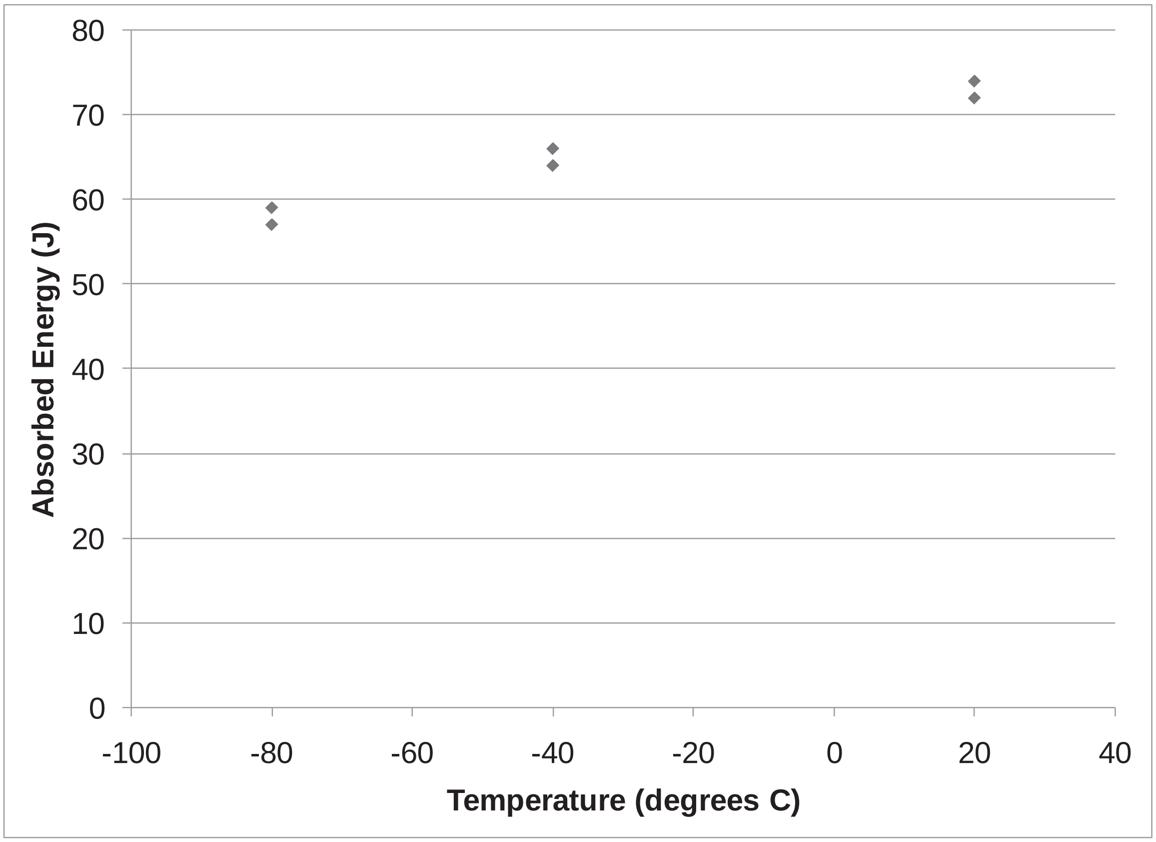


Figure 15: Base metal subsize Charpy impact behaviour.

While the fracture surfaces of the base metal samples were found to be ductile, the welded regions were brittle. Figure 16 is a photograph of the fracture surface of Sample -1 which has two distinguishable fracture morphologies. Adjacent to the notch the fracture appearance is brittle, while below this brittle region, the fracture is ductile. This brittle region was found to coincide with the width of the weld as illustrated in Figure 17. By measuring the distance from the upper surface of the Charpy specimen to the end of the brittle fracture face and also to the edge of the weld, the fraction of the weld that lies within the brittle region could be determined. The fraction of the weld which lies within the brittle fracture is summarized in the last column of Table 4, from which it is concluded that nearly all of the welded regions were brittle.

The limited weld cross-sectional area in the fracture surface generates deceiving results. When the limited weld cross section is neglected, both the impact energy and shear measurements listed in Table 4 meet the requirements listed in Table 3. However, both of these factors consider either the total energy to fracture the specimen or the total area of the fracture surface. When brittle fracture appearance of only the welded region is considered, all of the samples fail to meet the weld metal fracture appearance requirement.

Of interest is that the mode of fracture changed from being brittle within the weld to ductile in the HY-80 base metal. This demonstrates the influence that microstructure has on fracture, since the primary microstructural difference between the HY-80 base metal and weld metal was the tempering of the as-cast HY-80.

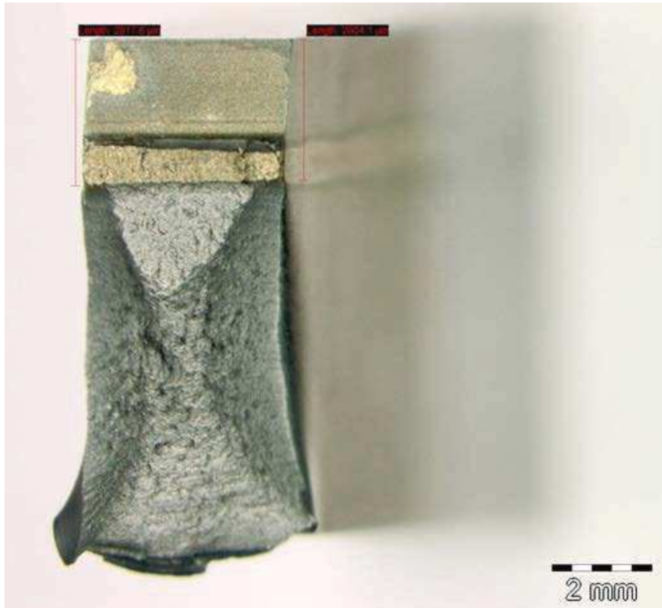


Figure 16: Fracture surface of the sample -1, etched for approximately 30 seconds in 10% Nitol.

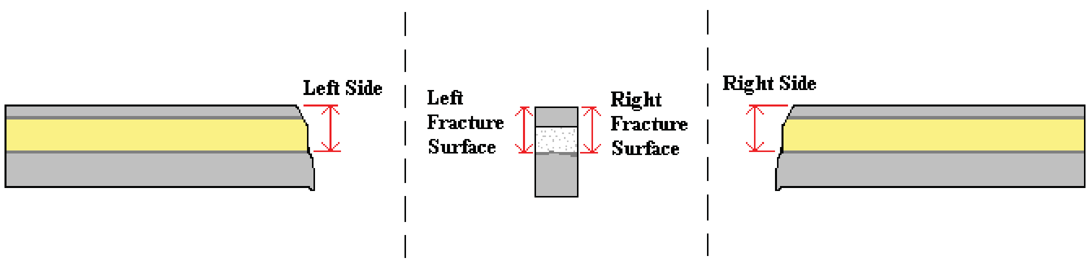


Figure 17: Method used to estimate the relative weld area within the brittle zone of the fracture face.

Table 4: Charpy impact summary including fracture appearance

Heat Input J/mm	Specimen	Test Temp. (Deg C)	Absorbed Energy (J)	Shear Area of Entire Fracture Surface (%)	Fraction of Weld Within Brittle Region (%)
75	-1	-92	32	77	96
	-3	-94	37	79	98
	-31	**-50**	**58**	90	98
108	-6A	-50	43	92	99
	-6A1	-50	47	90	95
	-6B	-50	46	91	96
	-6B1	-50	54	88	95
	Ave (-50C)		**48**	**90**	**96**
137	-2A	-94	30	72	95
	-2B	-91	23	58	97
	-2A1	-50	36	90	100
	-2B1	-50	40	87	94
	Ave (-50C)		**38**	**77**	**97**
210	-5A	-50	30	73	93
	-5A1	-50	32	77	94
	-5B	-50	32	78	94
	-5B1	-50	30	74	97
	Ave (-50C)		**31**	**76**	**95**
240	-3A	-50	27	68	95
	-3A1	-50	28	73	91
	-3B	-50	30	77	77
	-3B1	-50	26	69	91
	Ave (-50C)		**28**	**72**	**89**

4 Conclusions

The metallography and mechanical properties of a series of 5 mm thick HY-80 autogenously fibre laser welded samples were examined. These samples were welded over a range of heat inputs extending from 75 to 240 J/mm by varying both the travel speed and laser power. Apart from variations in the width of the fusion and heat affected zones and the presence of porosity, the metallography appeared similar. Microstructurally, the fusion zone is made up of an untempered martensite structure which has a nearly uniform hardness. Porosity was noted under all welding conditions, but became increasingly prevalent with increasing heat input.

Mechanical characterization included a transverse tensile and sub-size Charpy impact specimen. While the transverse tensile specimen passed the requirements of meeting the tensile strength of the base metal, the Charpy Impact specimens indicated that the weld metal was brittle at a test temperature of -50°C.

While weld-tempering procedures could be developed to produce a tempered martensitic structure, thereby improving the impact properties of the weld metal, the presence of significant concentrations of voids is highly undesirable. Further weld procedure development would be required in order to meet the stringent quality assurance standards for this application.

Without significant further development laser fibre welding would not be recommended for this type of application.

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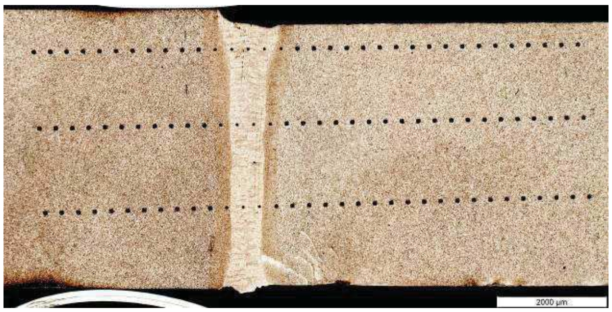
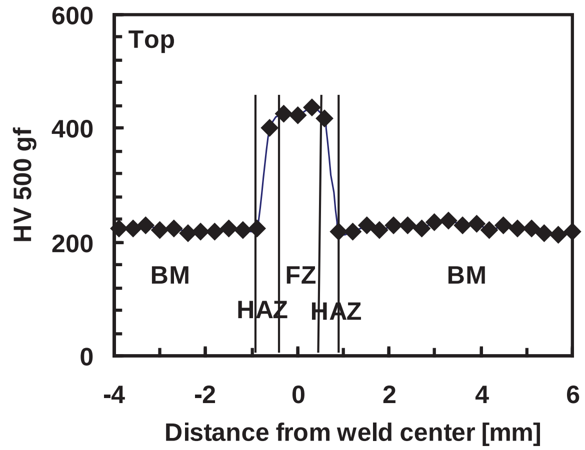
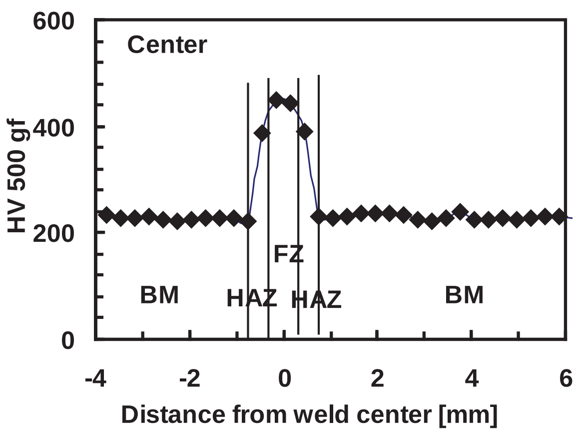
Annex A Microhardness Plots



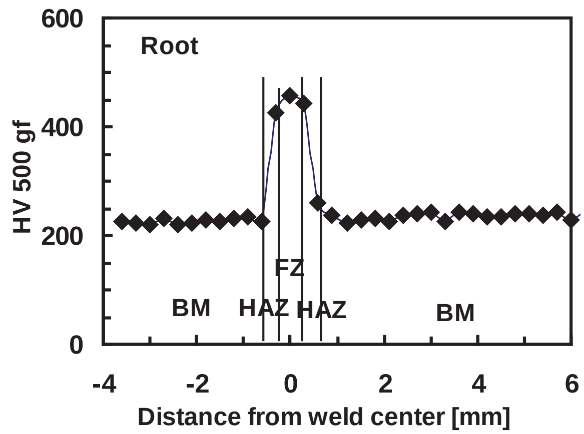
(a) Cross section



(b) Top

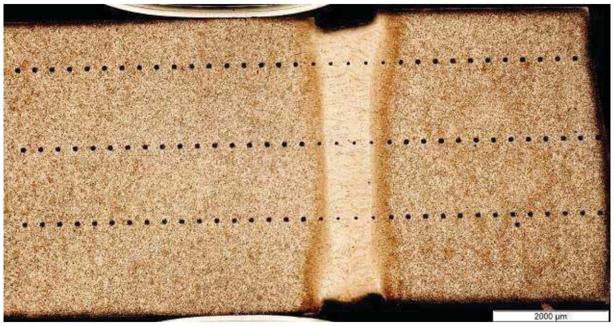


(c) Center

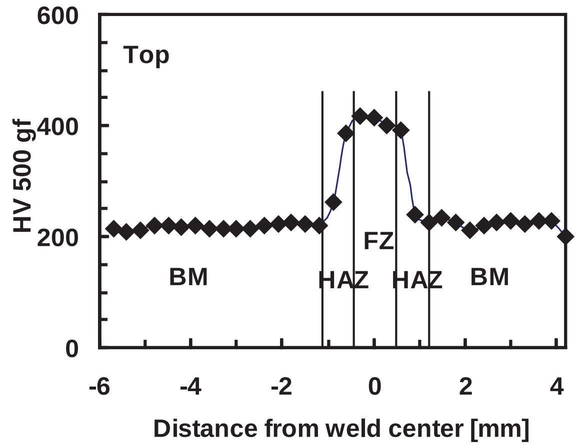


(d) Root

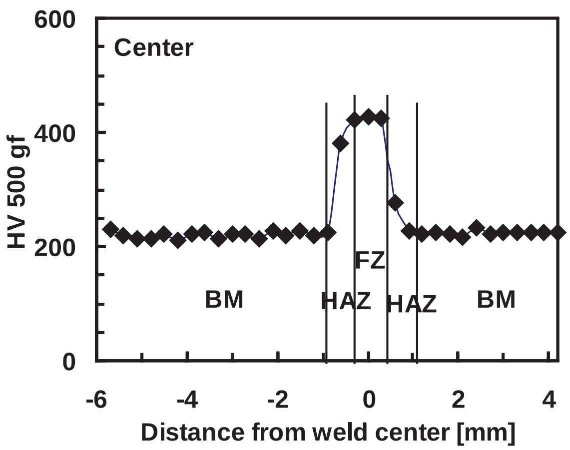
Figure 18: Hardness for Sample 3 (5 kW and 66.7 mm/s)



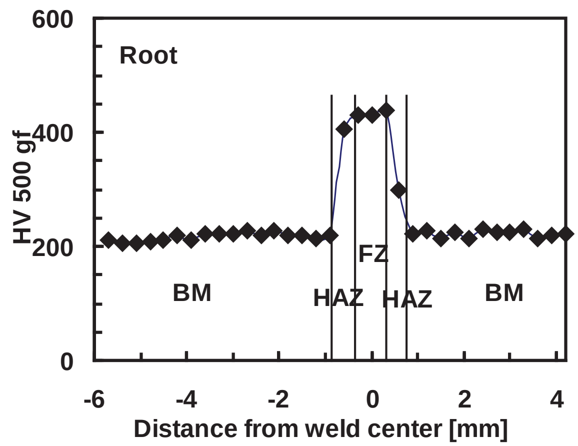
(a) Cross section



(b) Top

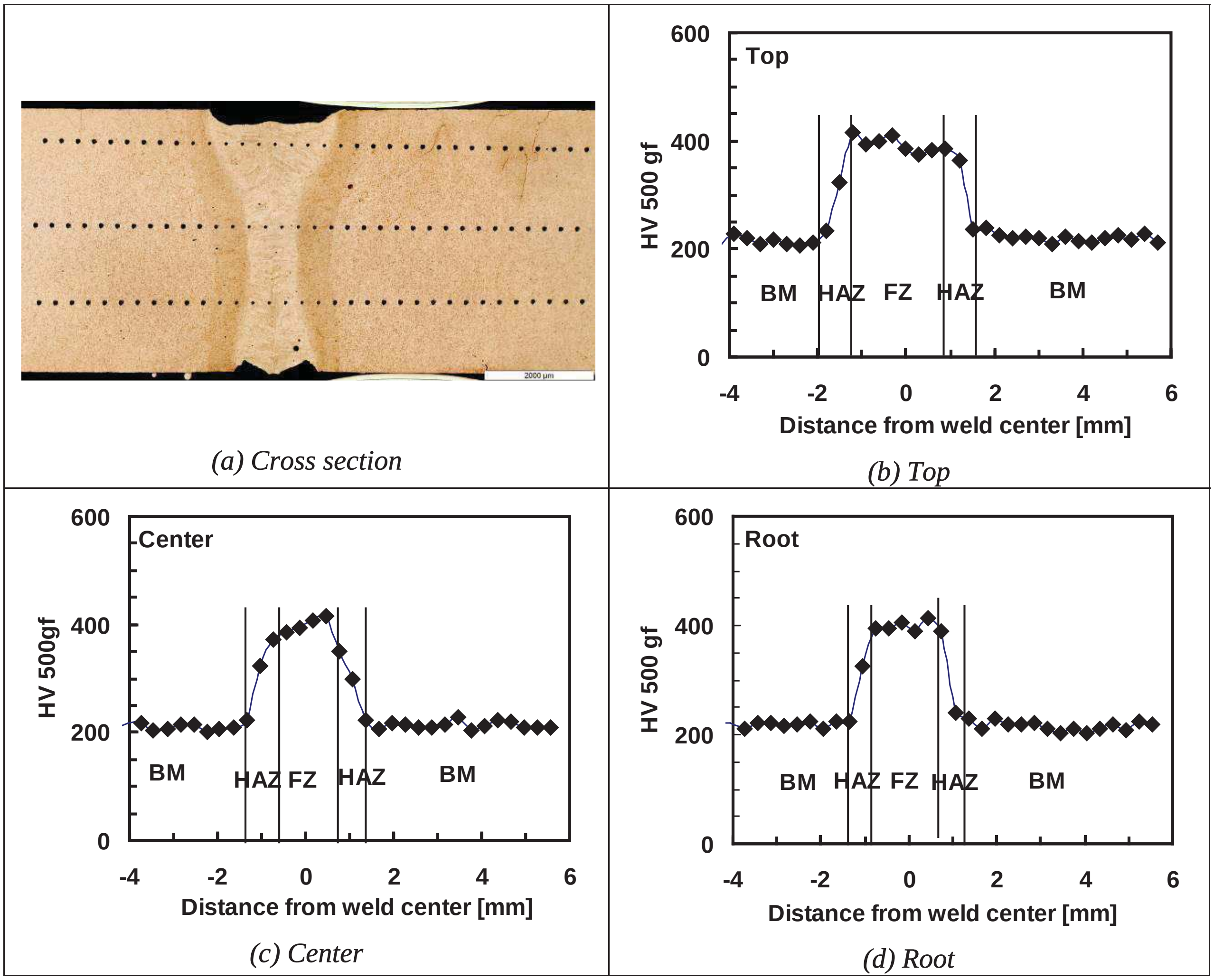


(c) Center



(d) Root

Figure 19: Hardness for Sample 6B (4.5 kW and 41.7 mm/s)



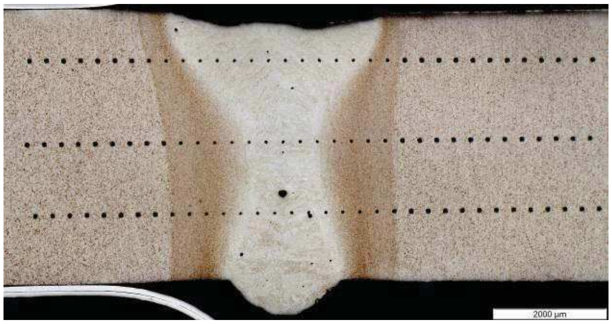
(a) Cross section

(b) Top

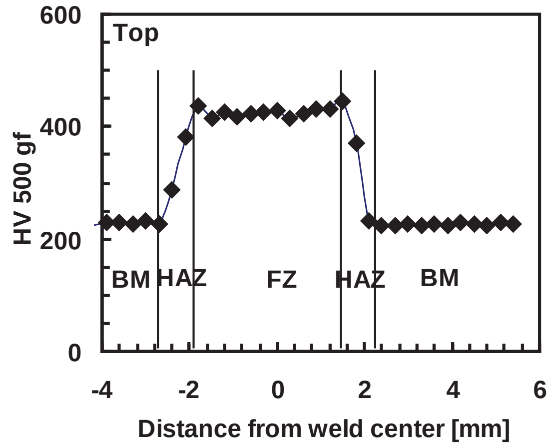
(c) Center

(d) Root

Figure 20: Hardness for Sample 2A (4 kW and 29.2 mm/s)



(a) Cross section



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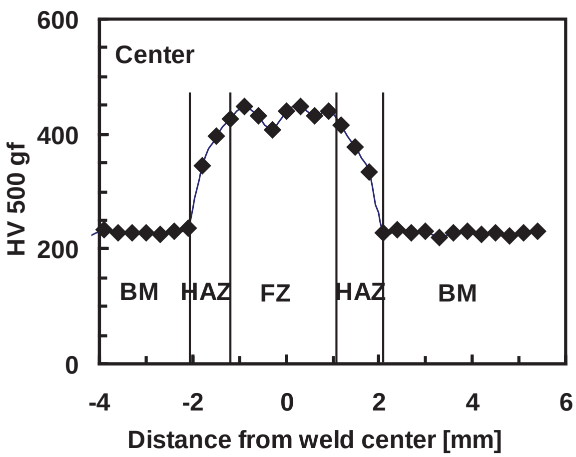
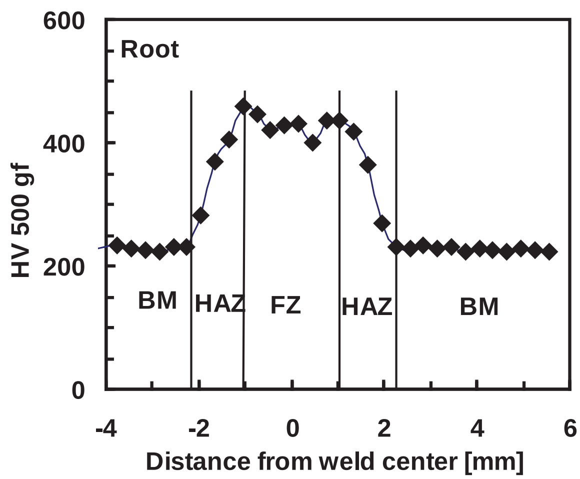
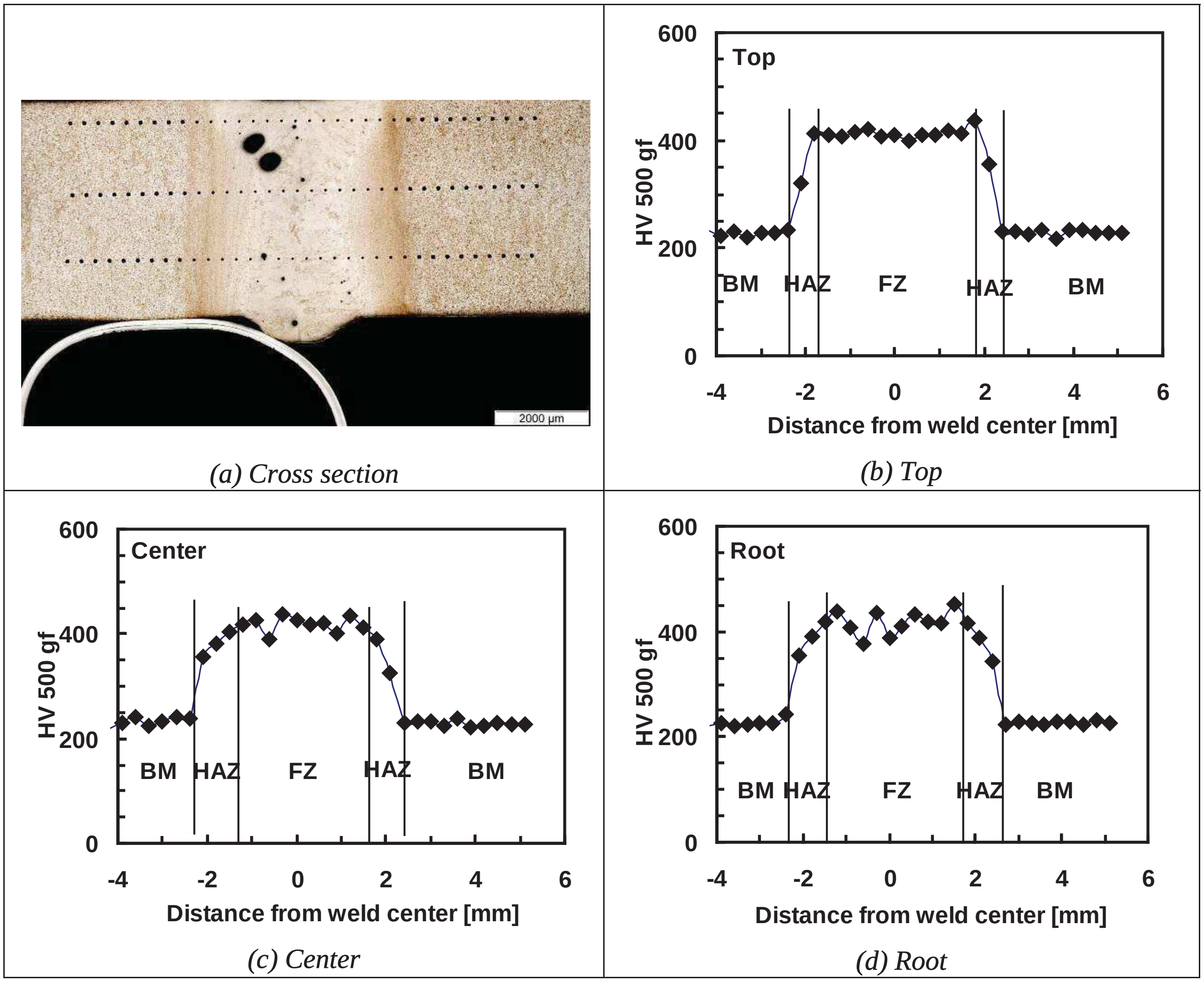


(c) Center



(d) Root

Figure 21: Hardness for Sample 5A (3.5 kW and 16.7 mm/s)



(a) Cross section

(b) Top

(c) Center

(d) Root

Figure 22: Hardness for 3A (3 kW and 12.5 mm/s)

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The metallurgical and mechanical properties of a series of autogeous fibre laser welded joints were carried out. These welds were made between two butt joined slices of 5 mm thick HY-80 material over a range of heat inputs extending from 75 to 240 J/mm. Apart from the increasing width of the fusion and heat affected zones with increased heat input, the metallurgical structures of the welds were similar. In all cases, the fusion zone of the weld was found to have the consistent hardness of an untempered martensite. Mechanical characterization of the welds showed that while the tensile strength exceeded the base metal requirements, under impact loading conditions the fusion zone failed in a brittle manner.

L’analyse des propriétés métallurgiques et mécaniques d’une série de joints réalisés par soudage autogène au laser à fibre a été effectuée. Ces soudures ont été réalisées entre des pièces d’acier HY-80 d’une épaisseur de 5 mm placées bord contre bord avec une plage de températures d’entrée de 75 à 240 J/mm. À l’exception de l’accroissement de la largeur des zones touchées par la fusion et par la chaleur en proportion de la température, les structures métallurgiques des soudures étaient semblables. Dans tous les cas, la zone de fusion de la soudure présentait la dureté uniforme d’une martensite non trempée. La caractérisation mécanique des soudures a révélé que, alors que la résistance à la traction dépassait celle des exigences relatives au métal de base, la zone de fusion se montrait cassante lorsqu’elle cédait en subissant une charge d’impact.

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laser welding; HY-80; thread repair

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